APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: MULTIUSER DSSS-OFDM MULTIBAND FOR ULTRA WIDEBAND COMMUNICATIONS

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Express Mail No.: ER 237057468 US

Date: 08/15/2003

MULTIUSER DSSS-OFDM MULTIBAND FOR ULTRA WIDEBAND COMMUNICATIONS

Background

This invention is generally relative to a multiuser direct sequence spread spectrum (DSSS) Orthogonal Frequency Division Multiplexing (OFDM) multiband based Ultra Wideband (UWB) Communications for a short-distance wireless broadband communication.

U.S. Federal Communications Commission (FCC) released a revision of Part 15 of Commission's rules regarding UWB transmission systems to permit the marketing and operation of certain types of new products incorporating UWB technology on April 22, 2002. With appropriate technologies, UWB device can operate using spectrum occupied by existing radio service without causing interference, thereby permitting scare spectrum resources to be used more efficiently. UWB technology offers significant benefits for Government, public safety, businesses and consumers under an unlicensed basis of operation spectrum.

In general, FCC is adapting unwanted emission limits for an UWB communication device that is significantly more stringent than those imposed on other Part 15 devices. In the indoor UWB operation, FCC provides a wide variety of UWB communication devices, such as high-speed home and business networking devices under Part 15 of the Commission's rules subject to certain frequency and power

limitations. Limiting frequency bands of certain UWB products, which is based on -10 dBm bandwidth of UWB emission for the indoor UWB operation, will be permitted to operate. The UWB communication device must operate in the frequency band ranges from 3.1 GHz to 10.6 GHz. UWB communication devices should satisfy the Part 15.209 limit for the frequency band below 960 MHz and must meet the FCC's emission masks for the frequency band above 960 MHz.

For the indoor UWB communication device, Table 1 lists a FCC restriction of the emission masks (dBm) along with the frequencies (GHz).

Table 1

Frequency (MHz)	EIRP (dBm)
0-960	-41.3
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

FCC also defines the UWB communication device as any device where the fractional bandwidth is greater than 0.25 based on the formula as follows,

$$FB = 2\left(\frac{f_H - f_L}{f_H + f_L}\right), \qquad (1)$$

where f_H is the upper frequency of -10 dBm emission points, and f_L is the lower frequency of -10 dBm emission points.

The center frequency F_c of UWB transmission is defined as the average of the upper and lower -10 dBm points as follows:

$$F_C = \frac{f_H - f_L}{2}. \quad (2)$$

In addition, a minimum bandwidth of 500 MHz must be used for the indoor UWB devices regardless of center frequency.

As the requirement, UWB communication devices must be designed to ensure that UWB operation can only occur in an indoor environment according to the indoor emission masks given in Table 1. UWB communication devices can be used for wireless broadband communications, particularly for a short-range high-speed data transmission suitable for broadband access to networks.

Given an 7.5 GHz UWB frequency ranges from 3.1 GHz to 10.6 GHz as a single frequency band, an analog-to-digital (A/D) converter and a digital-to-analog (D/A) converter must operate at a very high sampling rate F_s so that UWB communication receiver can implement in a digital domain. This leads to a high requirement for the A/D and D/A converters in the UWB transmitter and receiver. Presently, developing such a very high-speed A/D and D/A converter may not be possible with a reasonable cost, thereby having a difficult problem to apply the A/D and the D/A converter for an UWB communication transceiver based on single frequency band. On the other hand, a single frequency band-

based UWB communication transceiver does not have flexibility and scalability for transmitting and receiving a user data. In addition, the single frequency band-based UWB communication transceiver may have an interference with a WLAN 802.11a transceiver without using a special filter system since the WLAN 802.11a operates at a lower U-NII frequency range from 5.15 GHz to 5.35 GHz and at an upper U-NII upper frequency range from 5.725 GHz to 5.825 GHz.

An OFDM is an orthogonal multicarrier modulation technique that has been extensively used in a digital audio and video broadcasting, and the wireless LAN 802.11a. The OFDM has its capability of multifold increasing symbol duration. With increasing the number of subcarriers, the frequency selectivity of a channel may be reduced so that each subcarrier experiences flat fading. With such advantages, the OFDM approach has been shown in a particular useful for the wireless broadband communication over fading channels.

A DSSS is to use a pseudorandom (PN) sequence to spread a user signal. The PN sequence is an ordered stream of binary ones and zeros referred to as chips rather than bits. The DSSS can be used to separate signals coming from multiuser. The multiple access interference (MAI) among multiuser can be avoided if a set of PN sequences is designed with as low crosscorrelation as possible.

The multiuser DSSS-OFDM multiband for UWB communications is disclosed herein according to some embodiments of the present invention. The present invention uses eleven frequency bands as a multiband, each of the frequency bands having 650 MHz bandwidths along with the OFDM modulation for a multiuser UWB communication transceiver. The multiband OFDM solution allows using a low speed of the A/D and D/A converter. In addition, a unique of PN sequences is assigned to each user so that multiuser can share the same multiband to transmit and to receive information data based on the multiband OFDM of UWB technologies. On the other hand, since the OFDM is an orthogonal multicarrier modulation, subcarriers within each of the multi-frequency bands may be flexibility turned on or turned off avoiding the interference with the WLAN 802.11a during the indoor UWB operation. Moreover, the present invention of the DSSS-OFDM multiband for UWB communications has a scalability to transmit and to receive a data rate of 503.732 Mbps by using one of the multi-frequency bands up to a data rate of 5.541 Gbps by using all of the eleven multi-frequency bands.

Thus, there is a continuing need of the multiuser DSSS-OFDM multiband for UWB communication transceiver with employing architecture of PN sequences, OFDM multiband, multicarrier, and filtering for the indoor UWB operation.

Summary

In accordance with one aspect, a multiuser DSSS-OFDM multiband of UWB base station communication transmitter may comprise a multiuser encoding and spreading unit, a polyphase-based multiband, an IFFT unit, a filtering unit, and a multiband-based modulation and multicarrier.

Other aspects are set forth in the accompanying detailed description and claims.

Brief Description of the Drawings

FIG. 1 is a block diagram of showing a multiuser DSSS-OFDM multiband of UWB communication system with different user UWB mobile stations and a single UWB base station according to some embodiments.

FIG. 2 is a block diagram of showing a multiuser DSSS-OFDM multiband for an UWB base station communication transmitter according to some embodiments.

FIG. 3 is a detailed block diagram of showing a polyphase-based multiband according to some embodiments.

FIG. 4 is a detailed block of showing a 1024-point IFFT with employing 1000 subcarriers and 24 NULLs according to some embodiments.

FIG. 5 is a detailed block diagram of showing a filtering section according to some embodiments.

FIG. 6 is a detailed block diagram of showing a multiband-based modulation multicarrier according to some embodiments.

FIG. 7 is a detailed block diagram of showing a multiband QPSK modulation according to some embodiments.

FIG. 8 is a detailed QPSK constellation with a mapping relationship of bits and phases.

FIG. 9 is a frequency spectrum output of the multiuser DSSS-OFDM multiband of the UWB base station communication transmitter for the indoor UWB operation according to one embodiment.

FIG. 10 is a block diagram of showing a DSSS-OFDM multiband of UWB mobile communication receiver for a single user according to some embodiments.

FIG. 11 is a detailed block diagram of showing a combination subsection including an analog bandpass filter, multiband QPSK down converters and demodulations, A/D converters, and digital receiver filters according to some embodiments.

FIG. 12 is a detailed block diagram of showing a multiband QPSK demodulation and down converter according to some embodiments.

FIG. 13 is a detailed block diagram of showing a combination subsection including a fast Fourier transform (FFT) and frequency-domain equalizers (FEQ) according to some embodiments.

FIG. 14 is a detailed block diagram of showing a polyphase-based demultiband according to some embodiments.

FIG. 15 is a detailed block diagram of showing a despreading, deinterleaver, and decoding unit for a single user of the UWB mobile communication receiver according to some embodiments.

Detailed Description

Some embodiments described herein are directed to the multiuser DSSS-OFDM multiband-based UWB communication transceiver for the indoor UWB operation. The multiuser DSSS-OFDM multiband of UWB communication transceiver may be implemented in hardware, such as in an Application Specific Integrated Circuits (ASIC), digital signal processor, field programmable gate array (FPGA), software, or a combination of hardware and software.

Multiuser DSSS-OFDM multiband of UWB System

A multiuser DSSS-OFDM multiband of UWB communication system 100 for the indoor UWB operation is illustrated in FIG. 1 in accordance with one embodiment of the present invention. UWB mobile stations of 110a to 110p can communicate with an UWB base station 140 to transmit and to receive information data through multi-frequency bands in an indoor environment simultaneously. An UWB mobile station 110a transmits and receives the information data through its antenna 120a into air, and communicates with the UWB base station 140 through an antenna 130. In a similar way, other UWB mobile stations of 110b to 110p also transmits

and receives the information data through their antennas 120b to 120p, respectively, and communicate with the UWB base station 140 through the antenna 130 as well. The UWB base station 140 is coupled to an UWB network interface section 142 in which is connected with an UWB network 144.

Each of the UWB mobile stations of 110a to 110p uses a unique PN sequence to spread and despread a user source signal. The UWB base station 140 with knowing all of the PN sequences of the UWB mobile stations of 110a to 110p can transmit and receive all of the information data from all of the UWB mobile stations of 110a to 110p based on OFDM multiband solution by spreading and despreading of user PN sequences. The DSSS-OFDM multiband of UWB communication system uses a QPSK modulation and multicarrier within each of the multi-frequency bands to transmit and to receive the information data rate of 503.732 Mbps on one frequency band up to the information data rate of 5.541 Gbps on eleven frequency bands. As a result, the disclosed multiuser DSSS-OFDM multiband of UWB communication system 100 can transmit and receive the maximum data rate up to 5.541 Gbps by using all of the eleven frequency bands simultaneously.

UWB Base Station Transmitter Architecture

FIG. 2 is a block diagram of showing the multiuser DSSS-OFDM multiband of UWB base station transmitter architecture 200 for the indoor UWB operation according to

some embodiments. There are a number of *p* users with a user-1 bitstream 210a to a user-*p* bitstream 210p, respectively. The user-1 bitstream 210a is coupled to a 1/2-rate convolution encoder 212a in which is connected to an interleaver 214a. Using a unique PN sequence of a user-1 key 218a spreads the output sequence of the interleaver 214a. In a similar way, the user-*p* bitstream 210p is coupled to a 1/2-rate convolution encoder 212p that is connected to an interleaver 214p. Using a unique PN sequence of a user-p key 218p spreads the output sequence of the interleaver 214p. In addition, all of the PN sequences are orthogonal each other. This means that a cross-correlation between one PN sequence and other PN sequences is almost zero, while a self-correlation of a user PN sequence is almost equal to one. Then, the *p* output sequences from the interleaver 214a to the interleaver 214p in a parallel operation are added together to form a serial sequence output by using a sum over block duration 220. The serial output of the sum over block duration 220 is converted into eleven parallel sequences by using a polyphase-based multiband 230. Thus, the first of the output sequence from the polyphase-based multiband is converted into a 512-parallel sequence by suing an S/P 240a. The 512-parallel sequence is formed to 512-parallel complex sequence with symmetric conjugate. The 512-parallel complex sequence is passed through an IFFT 242a to produce

a 1024-parallel real sequence. The IFFT 242a is coupled to a guard 244a to insert 256 samples as a guard interval for the output sequence of the IFFT 242a. As a result, the output of the guard 244a is a 1280-parallel real sequence. Then, the 1280-parallel real sequences are passed through a filtering section 246a to produce even and odd modulated signal sequences. Carriers multiply the even and odd modulated signal sequences of the filtering section 246a by using a multiband-based modulation multicarrier 250. In the same way, the eleventh of the output sequence from the polyphase-based multiband 230 is converted into a 512-parallel sequence by suing an S/P 240k. The 512-parallel sequence is formed to 512-parallel complex sequence with symmetric conjugate. The 512-parallel complex sequence is passed through an IFFT 242k to produce a 1024-parallel real sequence. The IFFT 242k is coupled to a guard 244k to insert 256 samples as a guard interval for the output sequence of the IFFT 242k. Thus, the output of the guard 244k is a 1280-parallel real sequence. The guard interval is used to avoid an intersymbol interference (ISI) between IFFT frames. Then, the 1280-parallel real sequences are passed through a filtering section 246k to produce even and odd modulated signal sequences. Carriers multiply the even and odd modulated signal sequences of the filtering section 246k by using a multiband-based modulation multicarrier 250. Finally, the eleven paralleled output signal sequences

of the multiband-based modulation multicarrier 250 are added together and passed through a power amplifier (PA) 260 into air.

Referring to FIG. 3 is a detailed block diagram 300 of showing a polyphase-based multiband according to some embodiments. The polyphase-base multiband includes ten sample delays of 310a to 310k, eleven down samples of 320a to 320k, eleven RAM memories of 330a to 330k, and a modular counter 340. An input sequence with a length of N data is divided into eleven parallel sequences with a length of N/11 data by using the sample delays of 310a to 310j and the down samples of 320a to 320k. The eleven output sequences of the down samples of 320a to 320k are stored into RAM memories of 330a to 330k. A row size of each of the RAM memories of 330a to 330k is 512 and the number of bits in each row can be programmed. A modular counter is used to control an address of the RAM memories of 330a to 330k for storing input sequence and sending out output sequence.

Referring to FIG. 4 is a detailed block diagram 400 of showing a 1024-point IFFT 410 according to some embodiments. There are 24 Nulls including #0 (DC), and #501 to #523. The rest of the input #0 (DC) and #501 to #523 are set to zero. The coefficients of 1 to 500 are mapped to the same numbered IFFT inputs #1 to #500, while the coefficients of 500 to 1 are also copied into IFFT inputs

of #524 to #1023 to form a complex conjugate. Thus, there are a total of 1000 subcarriers for transmitting data and pilot information. In order to make a coherent detection robust against frequency offsets and phase noise, eight of the 1000 subcarriers are dedicated to pilot signals that are assigned into the subcarriers of #100, #200, #300, #400, and #624, #724, #824, and #924. These pilots are BPSK modulated by a pseudo binary sequence to prevent a generation of spectral lines. In this case, other 992 subcarriers of each OFDM are dedicated to assign for transmitting data information. After performing a 1024-point IFFT, an output of the 1024-point IFFT is cyclically extended to a desired length in each of the multiband.

The following table 2 lists data rate-dependent parameters of the 1024-point IFFT operation for each of the multi-frequency bands:

Table 2

Data rate (Mbits/s)	Modulation	Coding rate	Coded bits per sub-carrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
503.732	QPSK	1/2	2	1983.998	991.999

Table 3 lists the 1024-point IFFT of detailed timing-related parameters for each of the multi-frequency bands as well:

Table 3

Parameters	Descriptions	Value
N_{ds}	Number of data subcarriers	992
N_{ps}	Number of pilot subcarriers	8
N_{ts}	Number of total subcarriers	1000
D_{fs}	Frequency spacing for subcarrier (650MHz/1024)	0.6347 MHz
T_{FFT}	IFFT/FFT period (1/ D_{fs})	1.5755 μs
T_{gd}	Guard duration (T_{FFT}/4)	0.3938 μs
T_{signal}	Duration of the signal BPSK-OFDM symbol (T_{FFT} + T_{gd})	1.9693 μs
T_{sym}	Symbol interval (T_{FFT} + T_{gd})	1.9693 μs
T_{short}	Short duration of training sequence ($10 \times T_{FFT}/4$)	3.938 μs
T_{gd2}	Training symbol guard duration (T_{FFT}/2)	0.7877 μs
T_{long}	Long duration of training sequence ($2 \times T_{FFT}$ + T_{gd2})	3.938 μs
$T_{preamble}$	Physical layer convergence procedure preamble duration (T_{short} + T_{long})	7.876 μs

FIG. 5 is a detailed block diagram 500 of showing a filtering section 246 according to some embodiments. A switch unit 510 including two switches of 520a and 520b is used to split a serial data sequence into two parallel data sequences with an even and an odd number, respectively. The switch 520a rotates to the even number of data (for example, b_2, b_4, b_6, …) to form a serial even data sequence, and the switch 520b rotates to the odd number of data (for

example, b_1, b_3, b_5, …) to form a serial odd data sequence. Using a transmitter shaped filter 540a to shape the transmitter spectrum and limit the frequency band filters the serial even sequence of the switch 520a output. The output of the transmitter shaped filter 540a is passed through a D/A converter 550a in which is coupled to an analog reconstruction-filter 560a. The analog reconstruction-filter 560a does a smooth of signal of the D/A converter 550a output. In a same way, using a transmitter shaped filter 540b to shape the transmitter spectrum and limit the frequency band filters the output of the serial odd sequence of the switch 520b. The output of the transmitter shaped filter 540b is passed through a D/A converter 550b in which is coupled to an analog reconstruction-filter 560b. The analog reconstruction-filter 560b does smooth of the signal of the D/A converter 550b. A bit detector 530 identifies a value data of "0" or "1" from the output of the switch 520a and the switch 520b. The bit detector 530 is used to control a multiband QPSK modulation.

Referring to FIG. 6 is a detailed block diagram 600 of showing a multiband-base modulation multicarrier 250 according to some embodiments. Eleven analog signals of the output of the analog reconstruction-filters in parallel are passed through eleven multiband QPSK modulations of 610a to 610k in parallel. The bit detectors of 530a to 530k are

used to control the multiband QPSK modulations of 610a to 610k, respectively. The output signals of the multiband QPSK modulations of 610a to 610k are coherently added together by using a sum unit 620. Then, the output of the sum unit 620 is passed through an analog bandpass filter 630 to produce the bandlimited signals for transmitter.

Referring to FIG. 7 is a detailed block diagram 700 of showing a multiband QPSK modulation 610 according to some embodiments. The analog signals from the even and odd sequences in parallel are multiplied with carriers from an output of a multi-oscillator 710 by using multiplier units of 730a and 730b. The multi-oscillator 710 contains four carriers: $\sin(2\pi f_i t)$, $-\sin(2\pi f_i t)$, $\cos(2\pi f_i t)$, and $-\cos(2\pi f_i t)$. A switch 720a is used to connect with either a position of 712a or a position of 712b. In a same way, a switch 720b is used to connect with either a position of 714a or a position of 714b. Using the bit detector 530 controls both of the switches 720a and 720b. The switch 720a connects to the position of 712a when the bit detector 530 identifies "00" bits from the output of the switches 520a and 520b in FIG. 5. The switch 720a connects to the position of 712b when the bits detector 530 identifies "10" bits from the output of the switches 520a and 520b in FIG. 5. In a similar way, the switch 720b connects to the position of 714b if the bit detector 530 identifies "01" bits from the output of the switches 520a and 520b in FIG.

5. The switch 720b connects to the position of 714a if the bit detector 530 identifies "11" bits from the output of the switches 520a and 520b in FIG. 5. Then, a switch 740 rotates either a position of 730a or a position of 730b. The bit detector 530 also controls the switch 740. When the bit detector 530 identifies "00" or "10" bits from the output of the switches 520a and 520b, the switch 740 connects to the position of 730a. When the bit detector 530 identifies "01" or "11" bits from the output of the switches 520a and 520b, the switch 740 connects to the position of 730b. In this case, the outputs of the switch 740 are a QPSK modulation.

Referring to FIG. 8 is a detailed QPSK mapping relationship 800 according to two-bit information. A QPSK constellation 810 contains four mapping points, two points on the I-axis and tow points on the Q-axis. A mapping relationship of a bit pattern and a phase 820 contains four bit patterns along with the corresponding four-phase information. The bit patterns of "00", "01", "10", and "11" represent "0", "$\pi/2$", "π", and "$3\pi/2$" phases, respectively.

<u>Output Spectrum of UWB Base Station Transmitter</u>

FIG. 9 is an output frequency spectrum 900 of the multiuser DSSS-OFDM multiband of UWB base station communication transmitter, including eleven multi-frequency band spectrums of 920A to 920K according to some

embodiments. A FCC emission limitation 910 for the indoor UWB operation is also shown in FIG. 9. Each transmitter frequency bandwidth of the eleven multi-frequency band spectrums of 920A to 920K is 650 MHz and is fitted under the indoor FCC emission limitation 910 with different carrier frequencies. The detail positions of each transmitter multi-frequency band spectrums (dBm) along with the center, lower and upper frequencies (GHz) as well as the channel frequency bandwidth (MHz) are listed in Table 4:

Table 4

Multichannel Label	Center Frequency (GHz)	Lower Frequency (GHz)	Upper Frequency (GHz)	Frequency Bandwidth (MHz)
920A	3.45	3.125	3.775	650
920B	4.10	3.775	4.425	650
920C	4.75	4.425	5.075	650
920D	5.40	5.075	5.725	650
920E	6.05	5.725	6.375	650
920F	6.70	6.375	7.025	650
920G	7.35	7.025	7.675	650
920H	8.00	7.675	8.325	650
920I	8.65	8.325	8.975	650
920J	9.30	8.975	9.625	650
920K	9.95	9.625	10.275	650

During the indoor UWB operation, the fourth and/or fifth multi-frequency band of the multiuser DSSS-OFDM of

UWB base station transmitters can be turned off in order to avoid an interference with WLAN 802.11a lower U-NII frequency band and/or upper U-NII frequency band. In some cases, the multiuser DSSS-OFDM of the UWB base station and mobile transmitters can turn off some subcarriers within the OFDM in the fourth and/or fifth multi-frequency band if the WLAN 802.11a system only uses certain subchannels in the lower U-NII or in the upper U-NII frequency bands.

UWB Mobile Receiver Architecture

FIG. 10 is a block diagram of showing a DSSS-OFDM multiband of UWB mobile communication receiver 1000 for the indoor UWB operation according to some embodiments. A low noise amplifier (LNA) 1010, which is coupled to an automatic gain control (AGC) 1012, receives the multiuser DSSS-OFDM multiband-based UWB signals from an antenna 130 as shown in FIG. 1. The output of the LNA 1010 is passed through the AGC 1012 to adjust amplitude of the multiuser DSSS-OFDM multiband-based UWB signals for a multiband multicarrier down converter and demodulation 1020. The eleven bandlimited multiuser DSSS-OFDM multiband of UWB analog signals of the output multiband multicarrier down converter and demodulation 1220 are in parallel sampled and quantized by using an A/D converter unit 1022, with the sampling frequency rate at 720 MHz. The software and time control 1070 is used to control the AGC 1012, the multiband

multicarrier down converter and demodulation 1020, and the A/D converter unit 1022. Using a digital receiver filter unit 1024 to remove out of band signals filters the digital signals of output of the A/D converter unit 1022. The output digital signals of the digital receiver filter unit 1024 are passed through time-domain equalizers (TEQ) 1026. The TEQ 1026 is used to reduce the length of cyclic prefix to a more manageable number without reducing performance significantly. In other words, the TEQ 1026 can produce a new target channel with a much smaller effective constraint length when concatenated with the channel. Thus, the outputs of the TEQ 1026 in parallel are passed through a set of S/Ps of 1030a to 1030k to produce parallel digital sequences. Each of the S/Ps of 1030a to 1030k produces 1280 parallel digital sequences for each of guard removing units of 1032a to 1032k. The guard removing units of 1032a to 1032k remove 256 samples from the 1280 parallel digital sequences of the S/Ps of 1030a to 1030k to produce 1024 parallel digital sequences, which are used as inputs for FFT units of 1034a to 1034k. Each of the FFT units of 1034a to 1034k produces 512 frequency-domain signals that are used for frequency-domain equalizer (FEQ) units of 1036a to 1036k. The FEQ units of 1036a to 1036k are used to compensate for phase distortions, which are a result of phase offsets between the sampling clocks in the transmitter and the receiver of the multiuser DSSS-OFDM

multiband of UWB communication transceiver. This is because the phases of the received outputs of the multiband FFT units of 1034a to 1034k are unlikely to be exactly the same as the phases of the transmitter symbols at the input to the IFFT units of 242a to 242k of the multiuser DSSS-OFDM multiband of base station UWB transmitter in FIG. 2. Thus, the outputs of the FEQ units of 1038a to 1038k are passed through a set of P/S units of 1038a to 1038k to produce a serial sequence for all of the eleven multi-frequency bands. All of the serial sequences from the P/S units of 1038a to 1038k, with each sequence length of M, are added together to produce a sequence length of 11M by using a polyphase-based demultiband 1040. The output sequence of the polyphase-based demultiband 1040 is passed through a despreading, deinterleaver, and decoding unit 1050. The despreading, deinterleaver, and decoding unit 1050 perform despreading, deinterleaving and decoding for the multiuser DSSS-OFDM multiband of UWB mobile communication receiver.

Referring to FIG. 11 is a detailed block diagram 1100 of showing one combination subsection 1028 including an analog bandpass filter 1110, eleven multiband QPSK down converters and demodulations of 1120a to 1120k, twenty-two A/D converters of 1130a to 1130v, and twenty-two digital receiver filters of 1140a to 1140v according to some embodiments. The input signal of the AGC 1012 output as shown in FIG. 10 is passed through the analog bandpass

filter 1110, which is used to eliminate the out of band images. The output of analog signals of the analog bandpass filter 1110 is in parallel passed through the eleven multiband QPSK down converters and demodulations of 1120a to 1120k. Each of the multibands QPSK down converters and demodulations of 1120a to 1120k produces two analog signals as input signals for each of the A/D converters of 1130a to 1130v. The output digital signals of the A/D converters of 1130a to 1130v are in parallel passed through the digital receiver filters of 1140a to 1140k to produce the desired digital signals for the multiuser DSSS-OFDM multiband of the UWB mobile receiver. All of the A/D converters of 1130a to 1130v use the same bit resolution and the same sampling frequency rate. In a similar way, all of the digital receiver filters of 1140a to 1140v have the same filter attenuations and filter bandwidths with the same filter coefficients and a linear phase.

Referring to FIG. 12 is a detailed block diagram 1200 of showing the multiband QPSK down converter and demodulation 1120 according to some embodiments. The input signal r(t) of the analog bandpass filter 1110 output is passed through two multipliers 1210a and 1210b at the same time. The analog signal r(t) is multiplied with $\cos(2\pi f_i t)$ by using the multiplier 1210a to produce an analog baseband signal $r_1(t)$. In the same way, the analog signal r(t) is multiplied with $\sin(2\pi f_i t)$ by using the multiplier 1210b to

produce an analog baseband signal $r_2(t)$. Then anti-aliasing analog filters 1220a and 1220b filter both of the analog baseband signals $r_1(t)$ and $r_2(t)$ to produce the bandlimited analog signals for the A/D converters.

FIG. 13 is a detailed block diagram 1300 of showing a combination subsection including the FFT 1034 and the FEQ 1036 according some embodiments. The FFT 1034 has a 1024-point input of real-value and produce a 512-point complex data with labels of 0 to 511, while a 512-point complex data with labels of 511 to 1023 is disable. The FFT 1034 with labels of 0 to 511 also contains 12 Nulls. So, the FFT 1034 produces a 500-point complex data for the FEQ 1036. The FEQ 1036 contains 500 equalizers of 1310a to 1310z, 500 decision detectors of 1320a to 1320z, and 500 subtractions of 1330a to 1330z that operate in parallel. Each of the equalizers of 1310a to 1310z has N-tap with adaptive capability. Each of the decision detectors of 1320a to 1320z is a multi-level threshold decision. Each of the subtractions of 1330a to 1330z performs subtracting between the output of each of the equalizers of 1320a to 1320z and the output of each of the decision detectors of 1320a to 1320z. The output of each of the subtraction of 1330a to 1330z is referred to an error signal, which is used to adjust the N-tap coefficients of the each of the equalizers of 1310a to 1310z by using an adaptive algorithm 1330.

The phases of the received outputs of the FFT 1034 do not have exactly the same as the phases of the transmitter symbols at the input to the IFFT units of 242a to 242k of the multiuser DSSS-OFDM multiband of UWB base station transmitter as shown in FIG. 2. In addition, the phase responses have to consider the channel in which is coped with the TEQ 1026 as shown in FIG. 10. Thus, the FEQ 1036 in FIG. 13 is used to compensate for the phase distortion that is a result of a phase offset between the sampling clocks in the transmitter and the receiver of a multiuser DSSS-OFDM multiband of UWB communication transceiver. The FEQ 1036 also offers the additional benefit of received signal scaling before decoding since the FEQ 1036 can be used to adjust the gain of the FFT 1034 output so that the decision detectors of 1320a to 1320z can be set the same parameters for all subchannels regardless of the different subchannel attenuations.

FIG. 14 is a detailed block diagram 1400 of showing a polyphase-based demultiband 1040 according to some embodiments. The polyphase-base demultiband 1040 includes a modular counter of 1410, eleven RAM memories of 1420a to 1420k, eleven up samples of 1430a to 1430k, and ten sample delays of 1440a to 1440j. Eleven input sequences in parallel are stored into the RAM memories of 1420a to 1240k. A row size of each of the RAM memories of 1420a to 1420k is 512 and the number of bits in each row can be

programmed. The modular counter 1410 is used to control an address of the RAM memories of 1420a to 1420k for storing input sequences and sending out output sequences. The outputs of the RAM memories of 1420a to 1420k are interleaved each other to form a serial output sequence. The length size of the serial output sequence is 5632 per segment, which is used for the despreading, deinterleaver and decoding unit 1050 as shown in FIG. 10.

Referring to FIG. 15 is a detailed block diagram 1500 of showing the despreading, deinterleaver and decoding unit 1050 including a despreading 1510, an user-i key 1520, an deinterleaver 1530, a Viterbi decoding 1540, and a user-i bitstream 1550 according one embodiment. The output sequences of the polyphase-based demultiband 1040 are passed into the despreading 1510 by multiplying a spreading sequence of the user-i key 1520, which provides a unique key sequence. Cross correlations of the output sequences of the polyphase-based demultiband 1040 and the unique key spreading sequence of the user-i key 1520 produce an encoded user-i data bitstream. This encoded user-i data bitstream is then deinterleaved by using the deinterleaver 1530 that is also coupled to the Viterbi decoding 1540. The Viterbi decoding 1540 decodes the encoded user-i data bitstream to produce an original transmitted user-i data bitstream that is stored into the user-i bitstream 1550.

While the present inventions have been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of these present inventions.

What is claimed is: